

# **Sissejuhatus infotehnoloogiasse**

## **2. nädal: arvuti riistvara**

# Olulist abstraktsioonidest

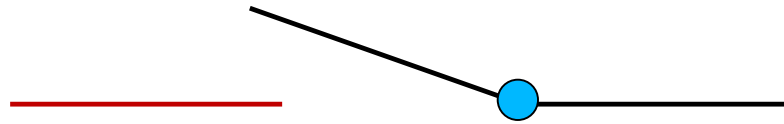
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- Kõrgkeeled, komponendid, võrguvärk jms on vajalik ainult selleks, et arendaja saaks rakendusi kiiremini teha.
- Arendaja mõtleb abstraktsioonide tasemel, aga lõpuks töötab kõik ikkagi transistoridel.
- **Abstraktsioonid nõ “tilguvad läbi”**: iga abstraktsiooni juures on vaja põhimõtteliselt aru saada, kuidas töötab alumine, vähem abstraktne tase.

- Loogikalülituste ehitamine releedest, lampidest või transistoridest
- Mikroprotsessori füüsiline ehitus
- Loogikalülitustest suuremate komponentide tegemine
- Mälu ehitus
- Protsessori tööpõhimõtte ja käsud
- Optimeeringud reaalses protsessorites

Olulisi detaile ja arusaamist neist teemadest leiad loengust/videost, powerpoint detailidesse ei lähe.

# Näpuga lüliti

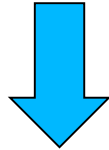


Vool läbi ei lähe

Elekter  
siit  
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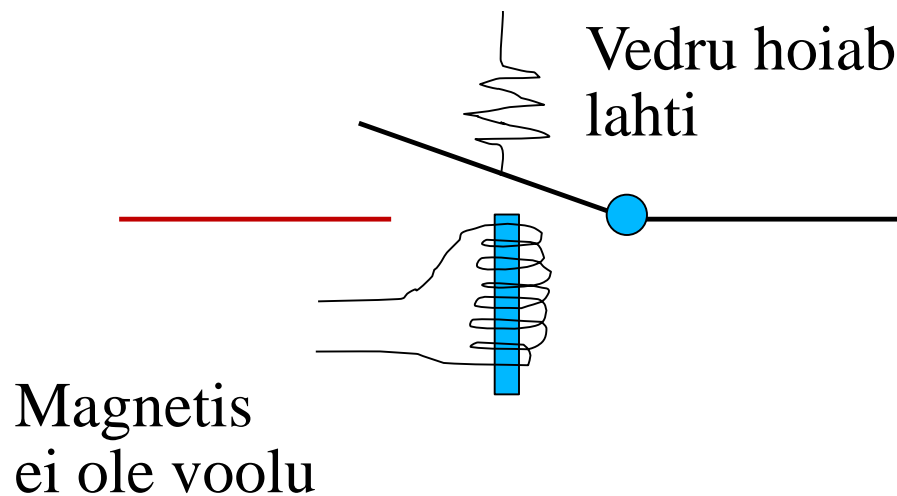
Vajuta  
näpuga

Elekter  
siit  
välja?

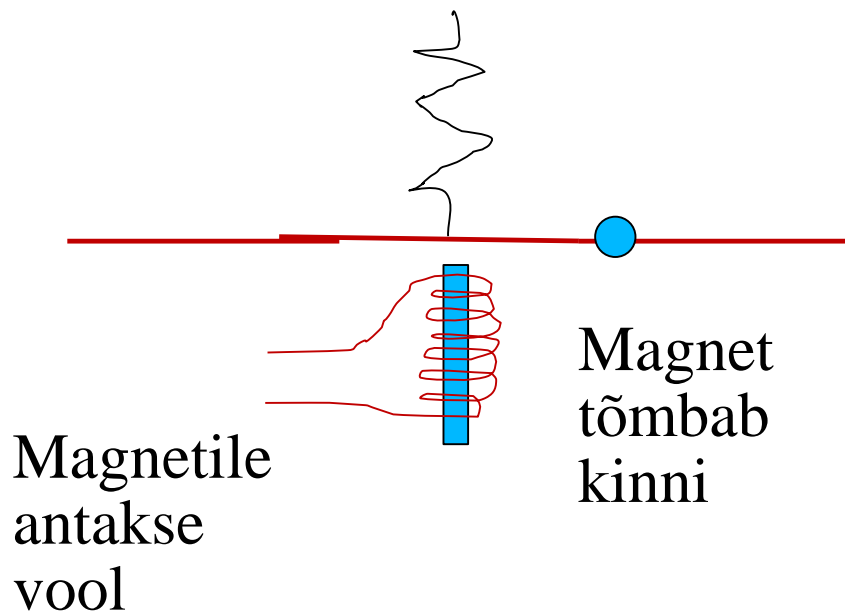


Vool läheb läbi

# Relee: mootoriga lüliti



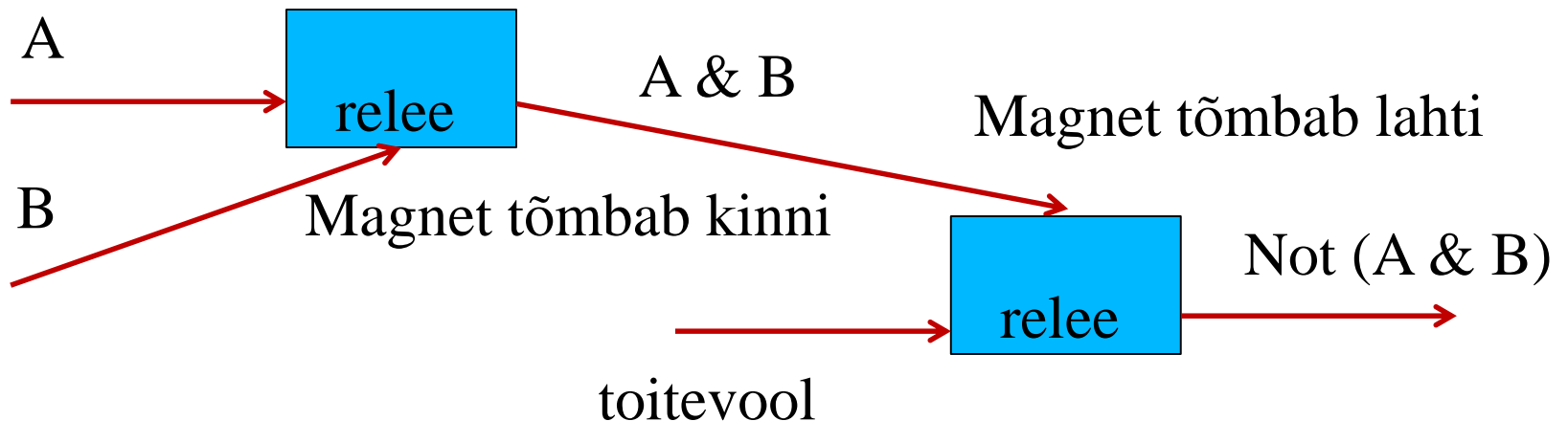
Vool läbi ei lähe



Vool läheb läbi

## Miks releed? Näide.

Realiseerime lausearvutuse valemi **Not (A & B)** releedega:

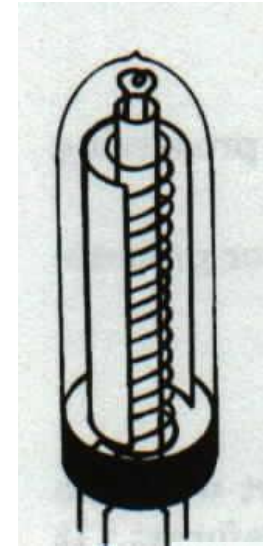


Keerukamaid asju, näiteks liitmist ja korrutamist, ehitatakse suure hulga lausearvutuse tehetena umbes samal moel.

# Raadiolambi tööpõhimõte

- Vacuum Tube (1906, Lee Deforest)

Three elements device used as electronic switch and amplifier: two electrodes separated by a grid in a vacuum glass enclosure.

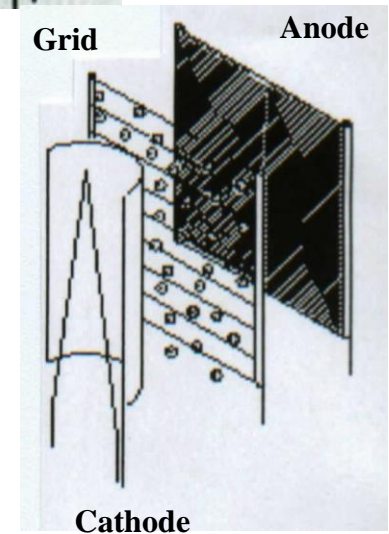


- Principle

*Cathode* - emits electrons;

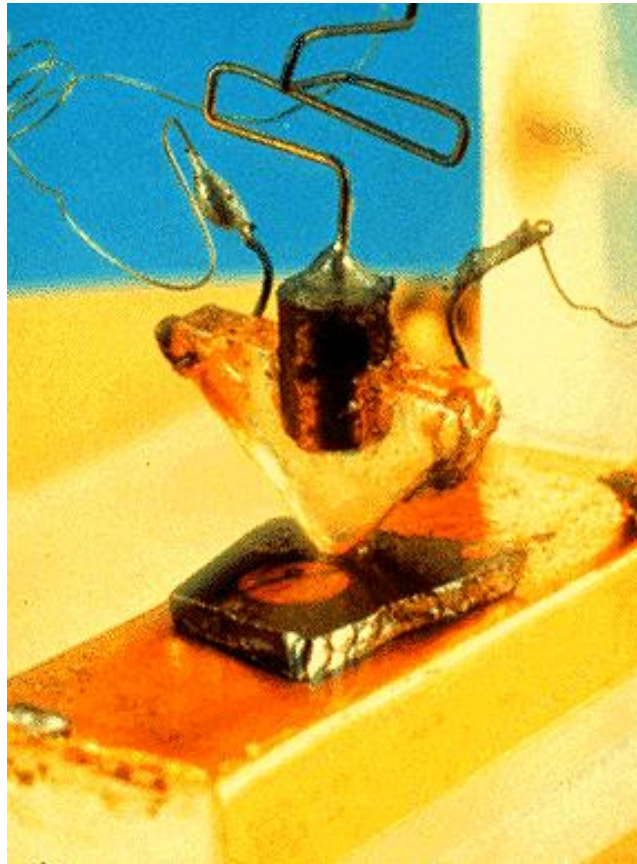
*Plate (anode)* - receives the electrons;

*Grid* - with negative bias voltage repels some of the electrons and prevents them from reaching the plate, resulting in less current flow. A changing negative charge on the grid modulates the plate current.



1947

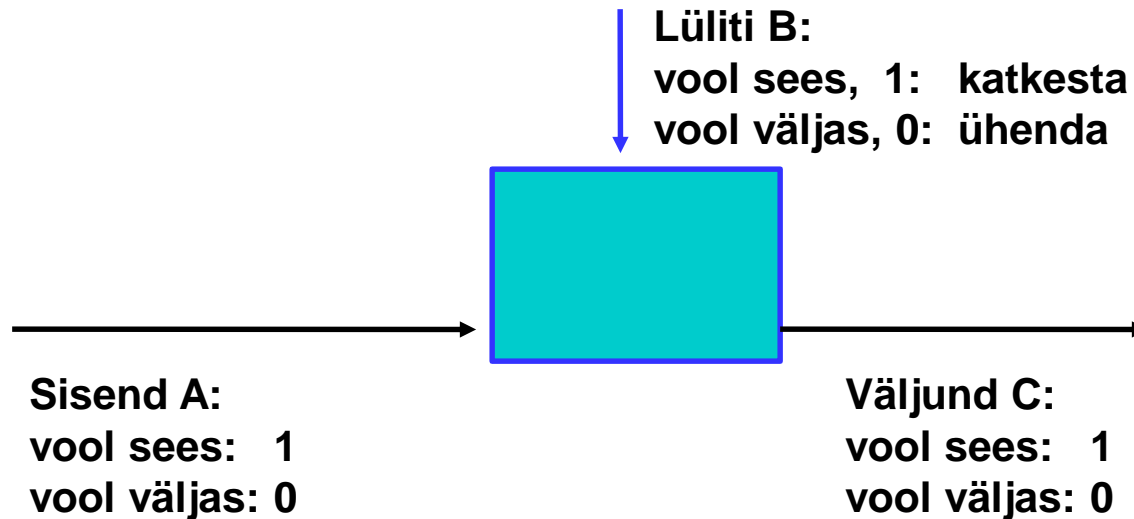
- Three scientists at **Bell Telephone Laboratories**, William Shockley, Walter Brattain, and John Bardeen demonstrate their new invention of the point-contact transistor amplifier.





# Komponendid

- Peamine idee: transistorid kui “katkestusmootoriga” lülitid

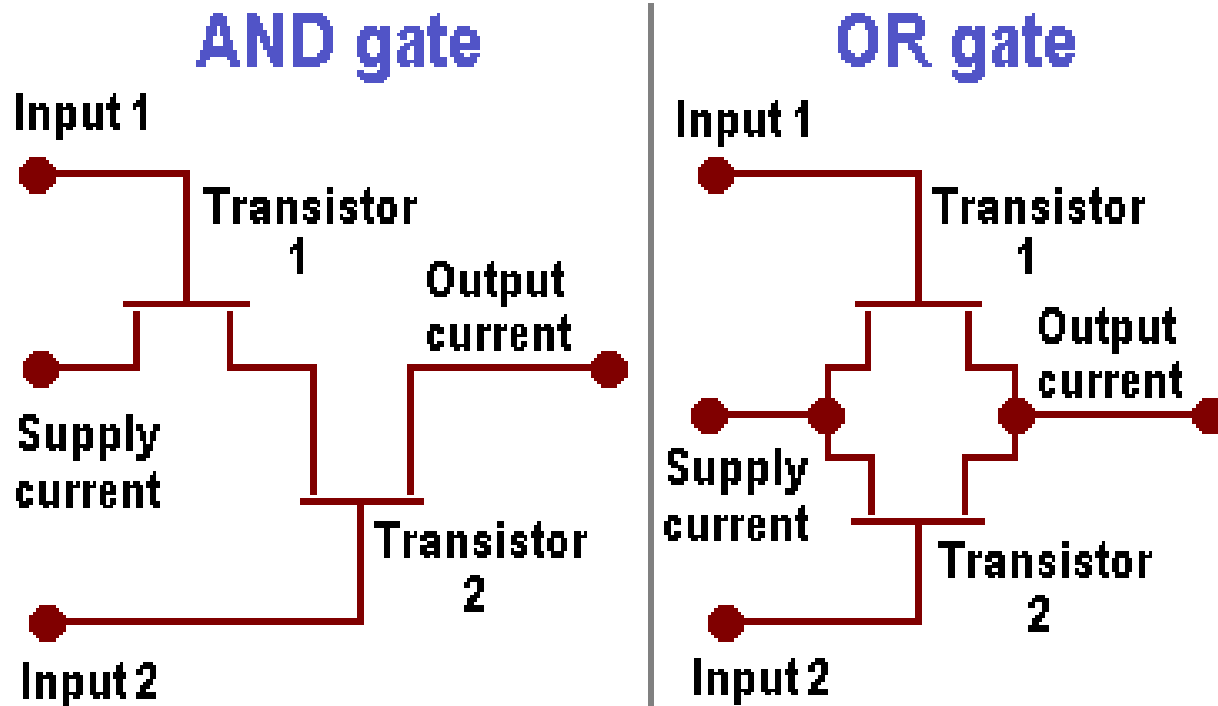


$$C = (A \text{ and } -B)$$

- Väikestest komponentidest ehitatakse suuremaid, millest omakorda veel suuremaid.
- Komponendid on kui mustad kastid: teame nende väljundit vastava sisendi korral, aga enamasti mitte nende tehnilist sisu.

## Logic gates: simple idea

- MOSFET: metal-oxide semiconductor field-effect transistor
- Input near 2V: circuit on. Input near 0V: circuit off.



# CMOS: transistor pairs for low power consumption

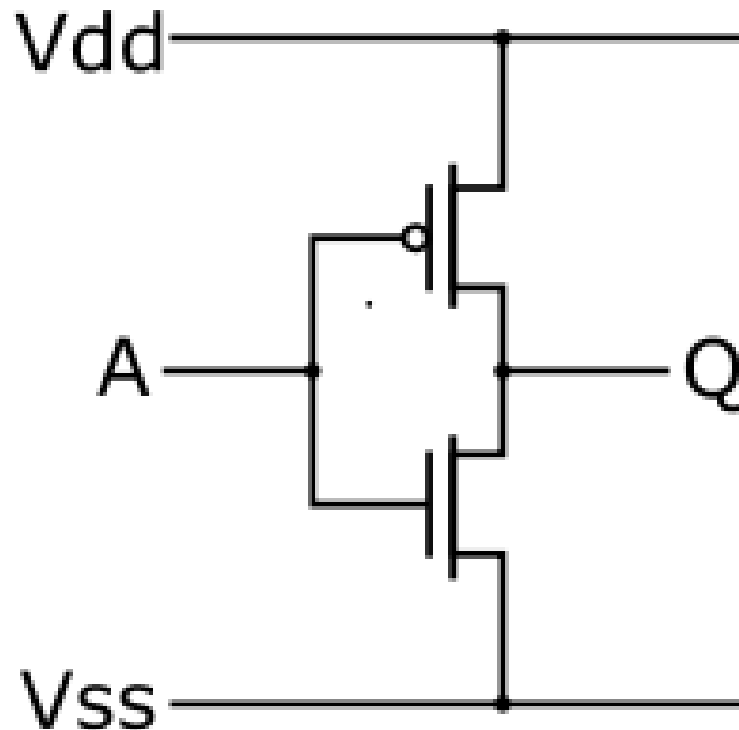
- MOSFET transistors always in complementary P/N pairs: switch only momentary, most of the time no current

- Inverter (not gate):

A: input

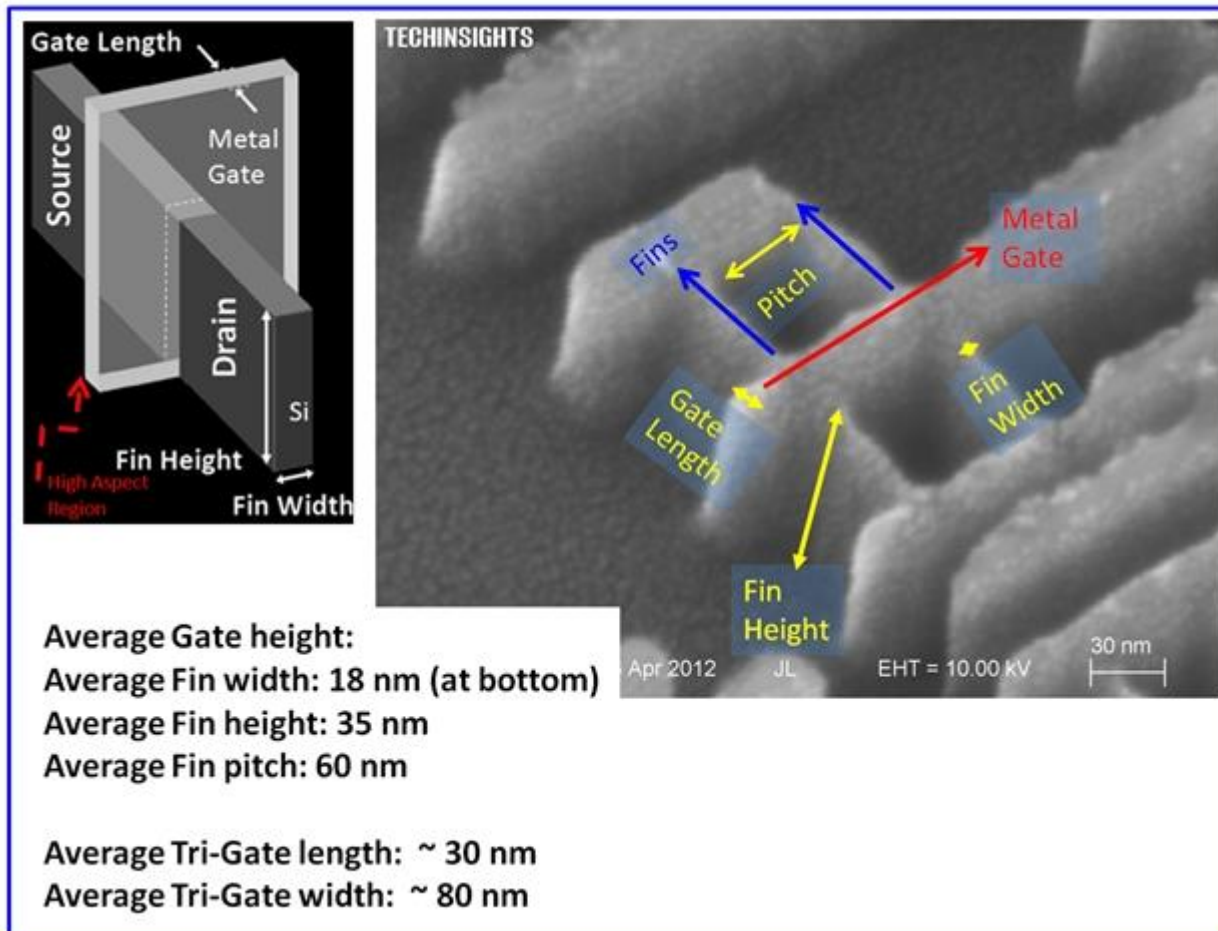
Q: output

One of the two transistors is always off, except for a short period during a switch



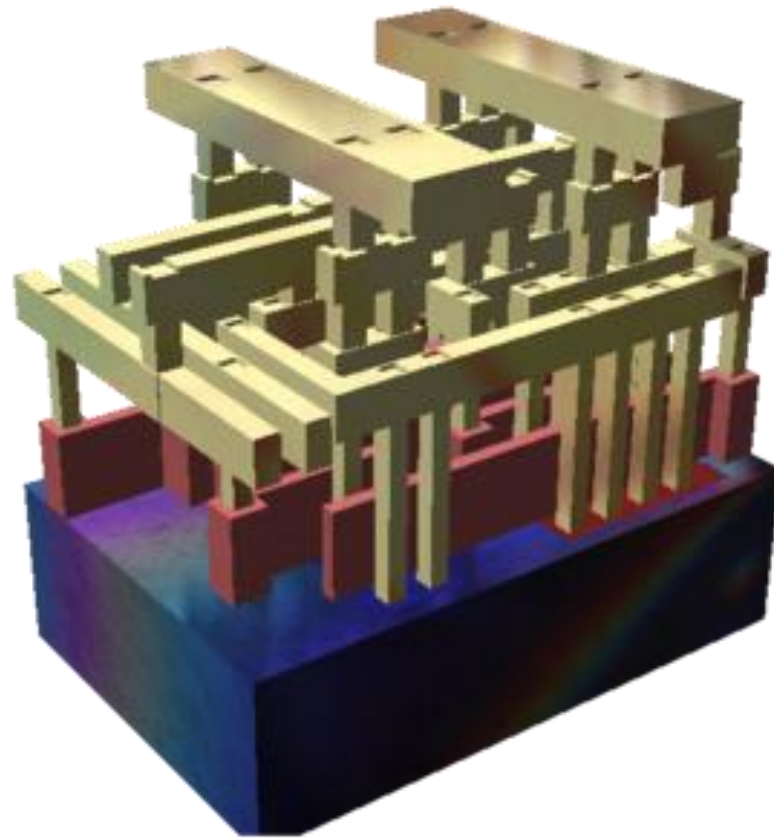
# Mikroprotessori sees

- Photo from Intel CORE i5-3550 processor: Ivy Bridge 22 nm process technology



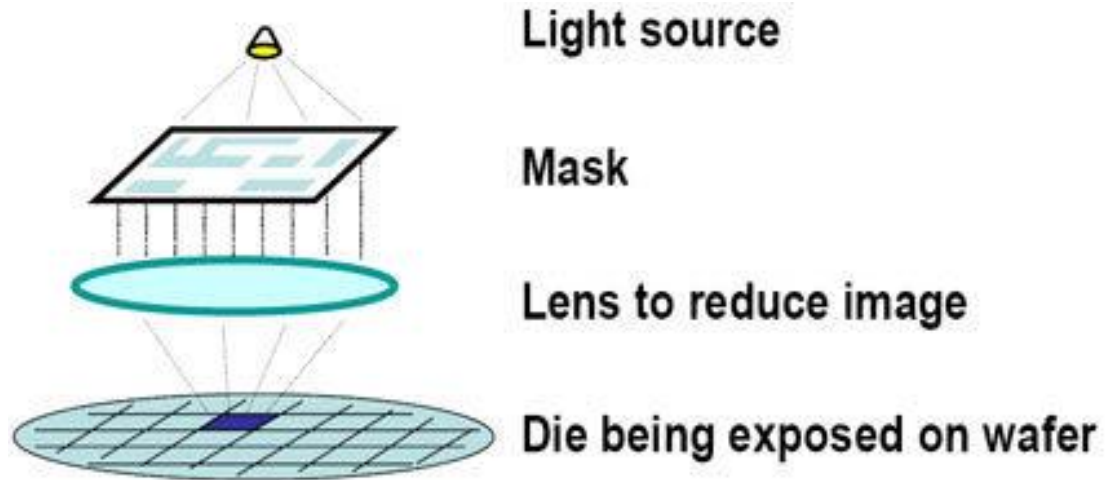
# Layers in an integrated circuit

- Blue: silicon bulk
- Red: polysilicon gates
- Yellow: metal wires



# Photolithography

- First a mask is made for each layer
- The mask is projected to a tiny area on the silicon wafer

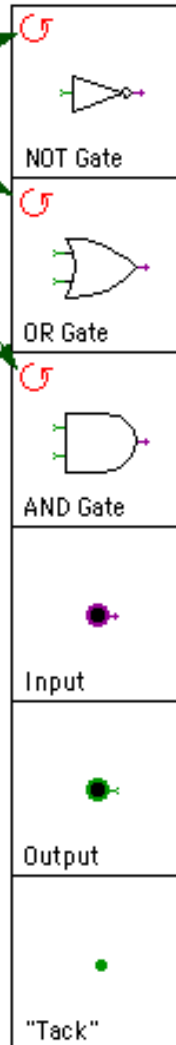
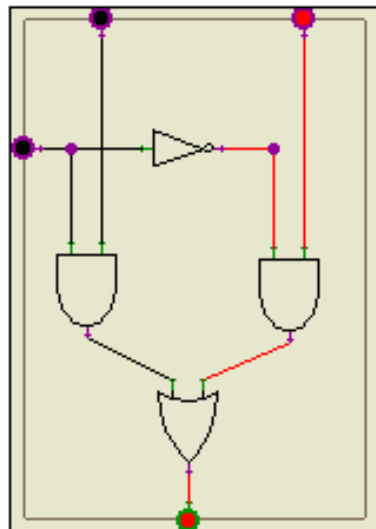


# Komponendid (Eck)

(A and C) or (B and (not C))

Click here to rotate  
a gate into one of  
four positions.

Sample circuit using  
all six components. The  
power is on. The output  
at the bottom, one of the  
inputs, and several wires  
are in the **ON** state.



**NOT gate** turns its output **ON** when its input is **OFF**, and vice versa. A NOT gate reverses its input.

**AND gate** turns its output **ON** when both of its inputs are **ON**. Otherwise, the output is **OFF**.

**OR gate** turns its output **ON** when either of its inputs is on (or when both are **ON**).

**Inputs** can be placed around the edges of a circuit to provide input values for the circuit as a whole.

**Outputs** can be placed around the edges of a circuit to represent values computed by the circuit as a whole.

**Tacks** are simply connecting points for wires, which can be used to help make your circuits neater.

# Komponendid (Eck)

**NB! Loe ja harjuta mõne simulaatoriga; vaata loengu lisamaterjalidest ntx Ecki simu:**

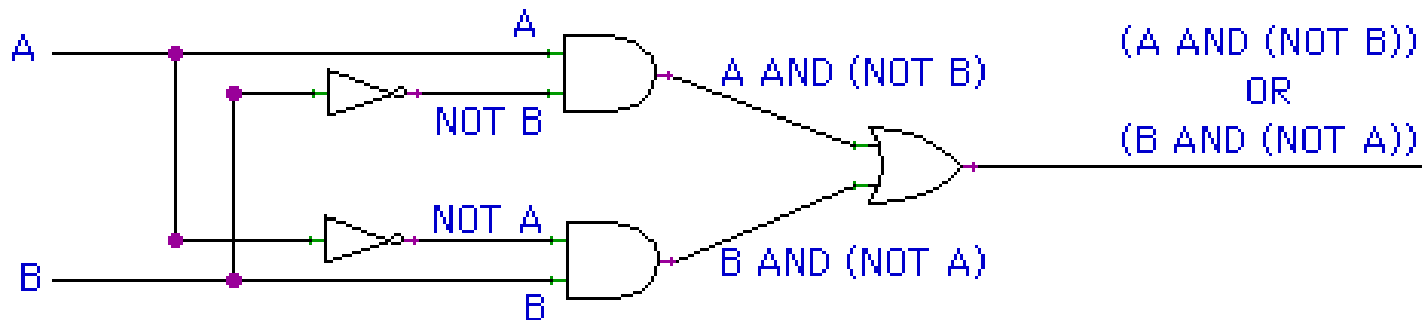
■ <https://math.hws.edu/eck/js/xLogicCircuits/xLogicCircuits.html>

**Head alternatiivsed simulaatorid:**

<https://www.kolls.net/gatesim/>

<https://circuitverse.org/simulator>

**(A and (not B)) or (B and (not A))**

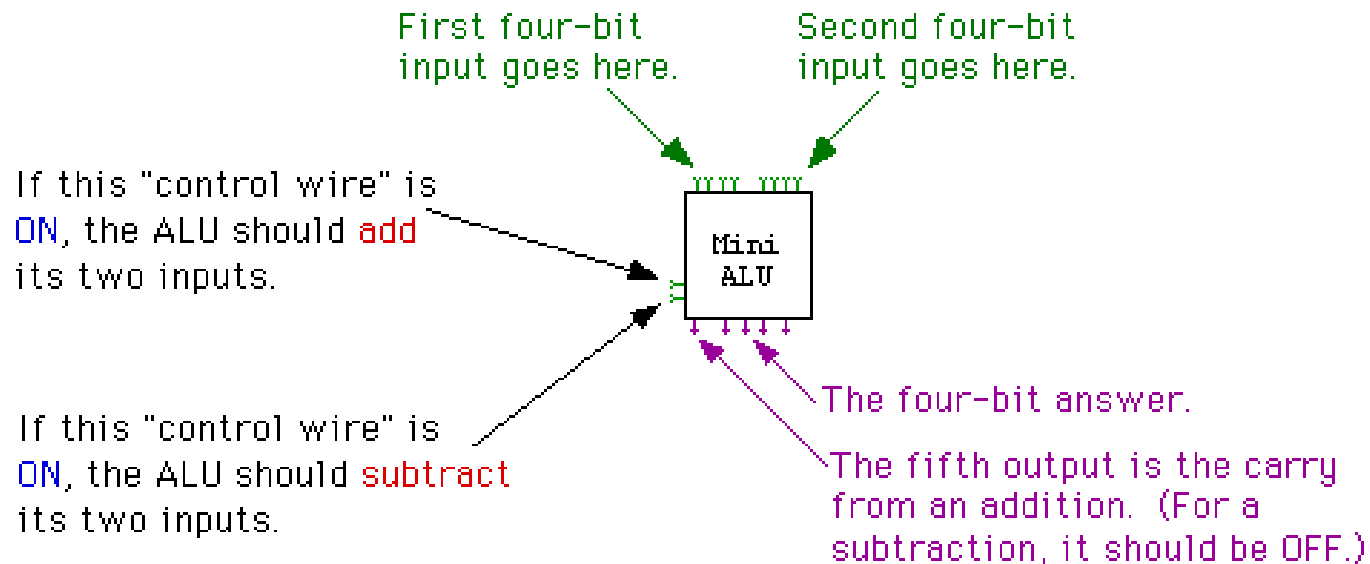




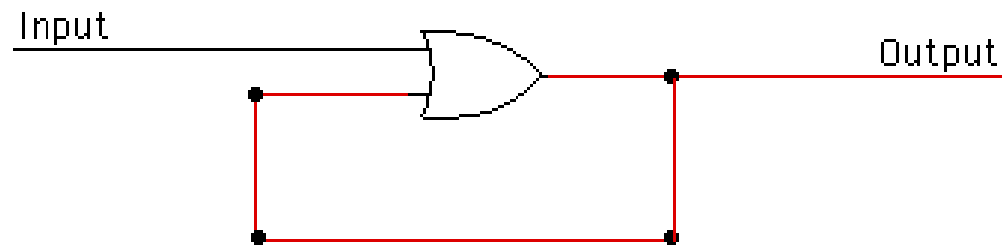
# Neljabitine liitja (four-bit adder)

- Kaheksa pluss kaks sisendjuhet, neli pluss üks väljundjuhet

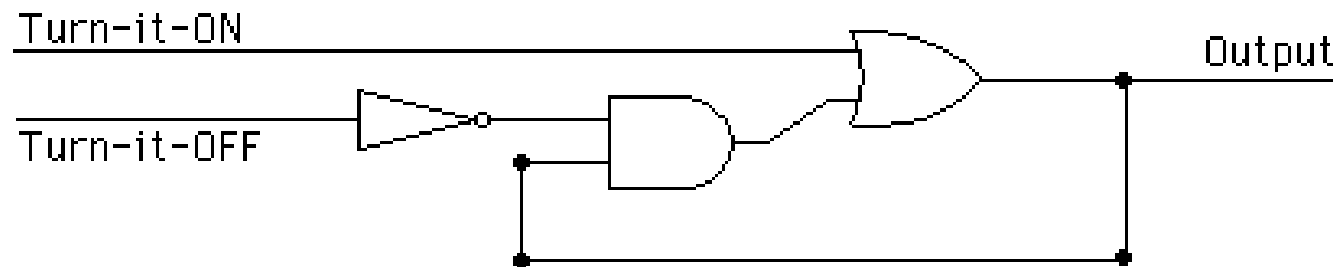
1011	1111	1111	1010	0111	0001
0110	0001	1111	0101	1010	0011
-----	-----	-----	-----	-----	-----
10001	10000	11110	01111	10001	00100



## ■ Tagasiside

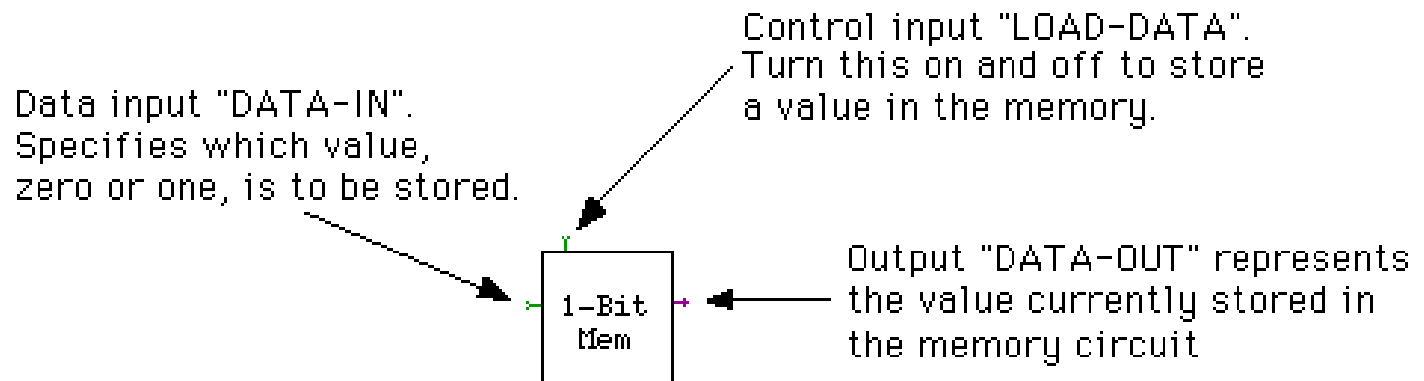


## ■ Lülitatav tagasiside: triger



# Ühebitine mälukiip

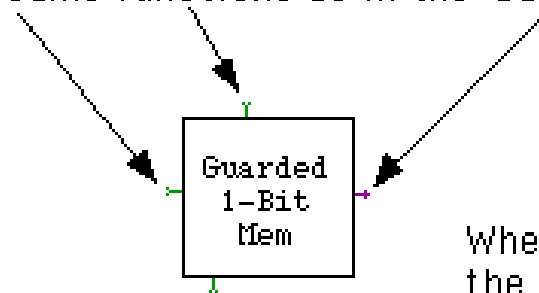
- Kaks sisend- ja üks väljundjuhe



# Guarded 1-bitine mäluikiip

- Ekstra lüliti kiibi sisse või väljalüülimiseks

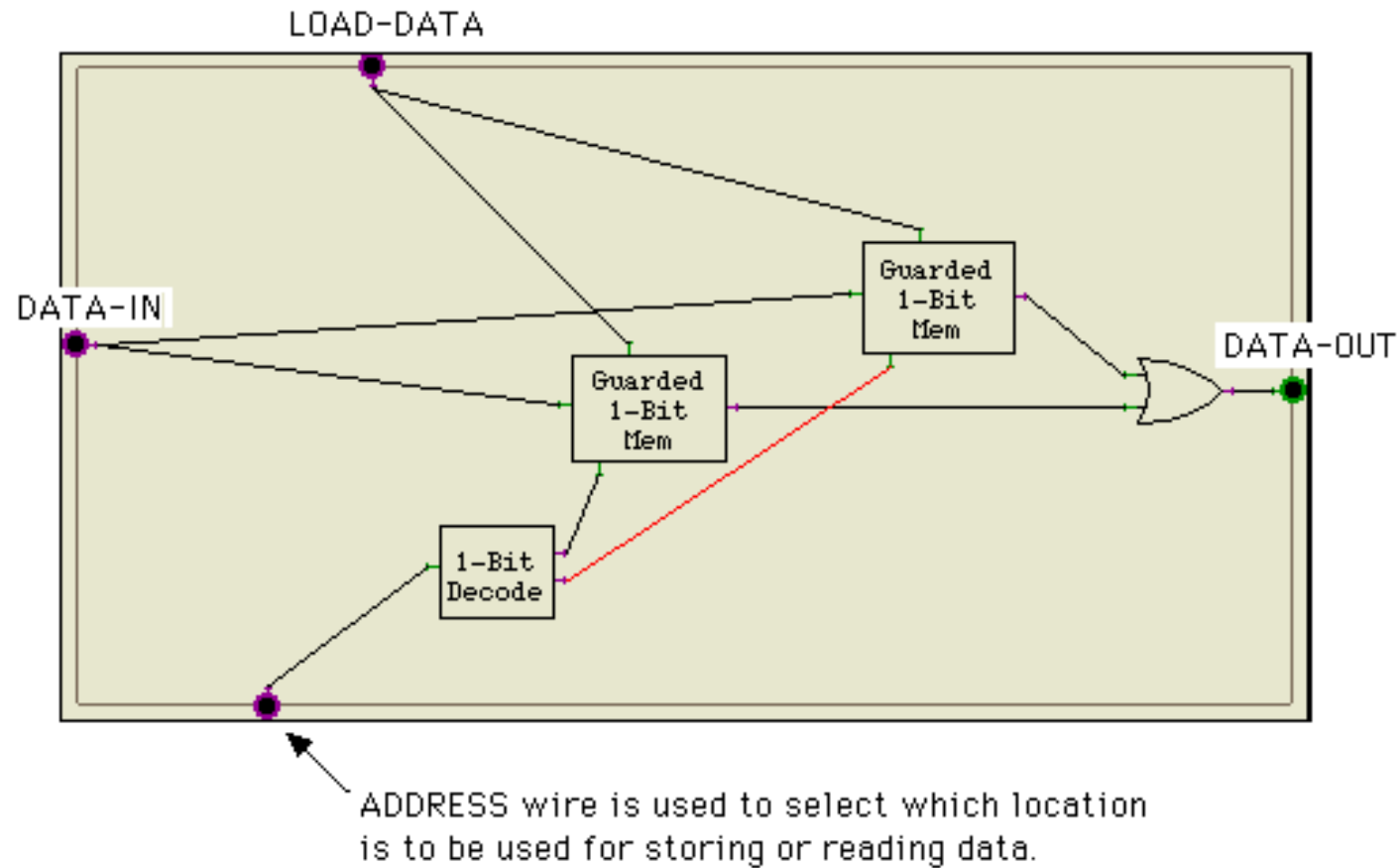
DATA-IN, LOAD-DATA, and DATA-OUT wires have the same functions as in the basic 1-Bit Mem.



When this GUARD control wire is OFF, the output is OFF and the LOAD-DATA wire has no effect. The GUARD must be ON to store or read data.

# RAM

## ■ Random-access memory



- <https://math.hws.edu/eck/js/xComputer/xComputer.html>
- Arvuti põhiosade (protsessor + mälu) simulatsioon väikese JS programmiga.
- Käsusüsteem sarnaneb väga esimeste päris-mikroprotsesoriga, a la 6502
- Lihtsama arusaadavuse tõttu kasutab kahebaidiseid mälupeši (16 bitti), mitte ühebaidiseid, nagu harilik arvuti.
- Mälu on 1024 pesa (1 K), seega 2 Kbaiti.
- Aadressi jaoks kasutusel 10 bitti.
- Esimestel koduarvutitel oli ka 4-16 Kbaiti (umbes sama hulk mälu)

- Olulist: protsessori sees on väike hulk spetsiaal-mälupesi (registrid)
- Tehteid saab teha ainult nende registrite vahel.
- Ei ole näiteks võimalik liita otse kahte mälus olevat arvu: enne tuleb nad registritesse kopeerida, siis seal liita, siis tulemusregistrist (nn akumulaator) mäll kirjutada.
- Koha, kust mälust loetakse/kirjutatakse näitab ADDR register.
- Koha, kust lugeda järgmine käsk, näitab PC (program counter) register

- **Kaks tsüklit üksteise sees:**
- **Välimine tsükkel** suurendab igal ringil PC-d (program counterit), st igal ringil võetakse täidetav käsk järgmisest mälupesast.
- **Sisemine tsükkel** toimub iga käsu sees. Sisemise tsükli jooksul täidetakse käsu sisemisi pisi-samme.

Üks pisi-samm vastab mingile juhtmele voolu peale andmisele, mispeale käivitub vastav loogika-ahel protessoris ja selle tulemus salvestatakse mõnda registrisse.

- **Masina taktsagedus** on see sagedus, kui tihti pisi-samme täidetakse. Iga järgmise pisi-sammu alustamise jaoks on masinas kell, mis annab kindla sagedusega impulsse. Pisi-sammu number saadakse nende impulsside kokkulugemisega.



## xComputer-i põhiregistrid

- The **X and Y registers** hold two sixteen-bit binary numbers that are used as input by the ALU. For example, when the CPU needs to add two numbers, it must put them into the X and Y registers so that the ALU can be used to add them.
- The **AC** register is the accumulator. It is the CPU's "working memory" for its calculations. When the ALU is used to compute a result, that result is stored in the AC. For example, if the numbers in the X and Y registers are added, then the answer will appear in the AC. Also, data can be moved from main memory into the AC and from the AC into main memory.
- The **FLAG** register stores the "carry-out" bit produced when the ALU adds two binary numbers. Also, when the ALU performs a shift-left or shift-right operation, the extra bit that is shifted off the end of the number is stored in the FLAG register.

## ... Registrid ...

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- The **ADDR** register specifies a location in main memory. The CPU often needs to read values from memory or write values to memory. Only one location in memory is accessible at any given time.
- The **PC** register is the program counter. The PC specifies the location in memory that holds the next instruction to be executed.
- The **IR** is the instruction register. When the CPU fetches a program instruction from main memory, this is where it puts it. The IR holds that instruction while it is being executed.
- The **COUNT** register counts off the steps in a fetch-and-execute cycle. It takes the CPU several steps to fetch and execute an instruction. When COUNT is 1, it does step 1; when COUNT is 2, it does step 2; and so forth. Remember that as the COUNT register counts 0, 1, 2,..., just one machine language program is being executed

# Hierarhia pistikutest progekeelteni

- Esimene: programmeerimismeetod: kaablid ja pistikud
- Teine: von Neumanni arhitektuur, programm mälus binaarkoodina:

01011101 01001011 01010101 11010101 10101001 . . . .

Lihtsam kirjutada hexas, nt 4A FC 09 B2 . . . .

- Kolmas: Esmane progekeel: assembler.

Üks masinakäsk: tüüpiliselt üks rida assembleriprogrammi

- Neljas: Harilik progekeel ehk nn kõrgkeel (fortran, basic, c, java, python jne jne).

Harilikud valemid, if-then-else jne, a la  $x = 2 * y + \sin(y) ;$

## Ecki assembler

- This program counts. It starts by putting the number 1 into memory location 12, and then it adds one to the number in that location over and over, forever.

```
LOD-C 1
STO 12
LOD 12
INC
STO 12
JMP 2
```

```
          LOD-C 1      ; Set Count equal to 1
          STO Count
Loop:     LOD Count    ; Add 1 to Count
          INC
          STO Count
          JMP Loop     ; Jump back to start of loop

          @12
Count:    data ; Location to be used for counting
```

## Reaalse protsessori ehitus ja käsud

- MOS 6502 : enimkasutatud protsessor esimestes mikroarvutites seitsmekümnenendatel (Apple I, II, Atari, Commodore jne)

[https://en.wikipedia.org/wiki/MOS\\_Technology\\_6502](https://en.wikipedia.org/wiki/MOS_Technology_6502)

- Sama protsessori käsustiku üpris täpne simulaator & hea õpik:

**<http://skilldrick.github.io/easy6502/>**

- Sama protsessori füüsiline simulaator brauseris:

<http://www.visual6502.org/JSSim/index.html>

# Väga erinevad arhitektuuritüübid

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- CISC ehk complex instruction set: Intel ja AMD
- RISC ehk reduced instruction set: ARM (mobiilid)
- Graafikaprotsessorid